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GNSS/IMU/Odometer based Train Positioning

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Usually train positioning is realized via counting wheel rotations (Odometer), and correcting at fixed locations known as balises. A balise is an electronic beacon or transponder placed between the rails of a railway as part of an automatic train protection (ATP) system. Balises constitute an integral part of the European Train Control System, where they serve as “beacons” giving the exact location of a train. Unfortunately, balises are expensive sensors which need to be placed over about 250 000 km of train tracks in Europe.

Therefore, recently tremendous efforts aim on the development of satellite-based techniques in combination with further sensors to ensure precise train positioning. A fusion of GNSS receiver and Inertial Navigation Unit (IMU) observations processed within a Kalman Filter proved to be one of potential optimal solutions for train traction vehicles positioning.

Today several hundreds of trains in Austria are equipped with a single-frequency GPS/GLONASS unit. However, when the GNSS signal fails (e.g. tunnels and urban areas), we expect an outage or at least a limited positioning quality. To yet ensure availability of a reliable trajectory in these areas, the GNSS sensor is complemented by a strapdown IMU platform and a wheel speed sensor (odometer).

In this study a filtering algorithm based on the fusion of three sensors GPS, IMU and odometer is presented, which enables a reliable train positioning performance in post-processing. Odometer data are counts of impulses, which relate the wheel’s circumference to the velocity and the distance traveled by the train. This odometer data provides non-holonomic constraints as one-dimensional velocity updates and complements the basic IMU/GPS navigation system. These updates improve the velocity and attitude estimates of the train at high update rates while GPS data is used to provide accurate determination in position with low rates. In case of GNSS outages, the integrated system can switch to IMU/odometer mode. Using the exponentially weighted moving average method to estimate of measurement noise for odometer velocity helps to construct measurement covariance matrices. In the presented examples an IMU device, a GPS receiver and an Odometer provide the data input for the loosely coupled Kalman Filter integration algorithm. The quality of our solution was tested against trajectories obtained with the software iXCOM-CMD (iMAR) as reference.